Bio-energy
“Now and Forever”

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On behalf of an interdisciplinary research team from the Schools of Agriculture, Engineering, and Science

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Now

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Where 25% of world’s oil is

Almost all of the oilfields in the Middle East would fit into the north-central region of the United States. More than a quarter of the world’s oil production comes from this limited area. (Jeffrey L. Ward)
**Pumping Oil (like water)**

**US Production capacity**, about 8 million barrels per day
about **533,000 oil wells**, about 17 barrels per well per day.

**Saudi capacity**, similar at about 8-9 million barrels per day
about **750 wells**
about 12,000 barrels per well per day
How many gallons of gasoline come from a barrel of oil?

Each 42-gallon barrel makes about 19½ gallons of gasoline.

U.S. gasoline consumption (March, 2005)
320,500,000 gallons per day
about 3700 gallons per second.

US Imports = $150 billion per year

http://www.gravmag.com/oil.html
Where the Refineries Are

Nearly half of U.S. oil refineries are clustered along the hurricane-prone Gulf of Mexico.

Yuma County, Ariz.: Proposed location of the Arizona Clean Fuels refinery

Source: National Petrochemical & Refiners Association
2004 Ethanol Production Facilities

U.S. Ethanol Production Facilities

Source: Renewable Fuels Association, January 2005
Integral Part of US Energy Security

Ethanol from corn
used in 12% of US gasoline
accounts for about 1% of total liquid fuel (= 690 million Bushels Corn)

Soy diesel
potential as an additive

Ethanol from corn and Biodiesel from soy have environmental benefits
some impact on global warming
may be higher cost than petroleum derived fuels
Costs

Dry Grind Ethanol Facilities

Currently grind corn and ferment to ethanol cost about $1.05 / gal capacity

(100 million gal per year)

Petroleum Refinery (rough ballpark estimate)

$2.5 billion / 150,000 barrels / day

calculates to about $1 / gal capacity
Ethanol Energetics

Is there a net energy gain?

35% if ethanol produced from grain
50-60% if ethanol produced from grain and cellulosic biomass

Compare to 85% energy gain when liquid fuels derived from petroleum
About Oil

Hubbert’s Peak

Peaking of world oil production
(Thanksgiving, 2005?)

(25 to 38 billion barrels per year)

Deffeyes, 2005
M. King Hubbert (Hubbert’s Peak, or the “Big Rollover”)

M. King Hubbert was well known among geologists for several innovative ideas, usually backed by mathematical analysis. After his prediction of the U.S. oil production peak came true, conservationists considered Hubbert to be a folk hero. (© George Tames, The New York Times)

Deffeyes, 2005
Energy > Oil

**Oil** = Energy + Chemicals

- Petroleum
- Soybeans, Other Vegetable Oils

Energy =

- Oil + Gas + Coal + Nuclear + Wind + Solar + Hydro + Bio-renewable Resources + H₂ + Inorganics
US Electricity Generation

Trillions Kw-hours / yr

Coal 1.97
Nuclear 0.75
Natural Gas 0.61
Hydrolelectric 0.27
Oil 0.109
Other 0.084

TOTAL 3.8

Oil represents about 3% of total
Ecomagination (not in dictionary yet)

Wall Street Journal, May 9, 2005
Coal Smoke Stack

Wall Street Journal, May 9, 2005
Efficiency and Conservation

Wall Street Journal, May 9, 2005
Oil = Transportation + Chemicals

Oil is a small component of electrical energy use
Oil is very BIG as liquid transportation fuel
Tight supplies give highly variable prices
Gas prices also go higher
May run out soon (2020, 2050, 2100?)
**Not Oil**

**Gas:** US consumes 60 billion ft$^3$/day

**Coal:** 6000 mines in US – 200 yrs supply

**Oil Shale:** Green River, Utah 1.5 trillion bbls (one bbl per ton); Mideast 400 billion bbls oil

**Uranium:** At least 50 years supply

Deffeyes, 2005
And Forever
Picture of everyone’s My Yard (MY)
Using Hay

1 Bale = 970 lbs = 2000 miles

Assuming 50 gal x 40 mpg
Making Ethanol

Convert Hay to sugars (enzymes)
Convert Sugars to yeast (fermentation)
Remove water from ethanol (separations)
Blend ethanol with gasoline

E10 = 10% ethanol
E85 = 85% ethanol
MY?
500 MW = 666 windmills = 140,000 people

A typical (750 kW) wind turbine provides enough power for 328 typical (non-electric heating) homes.

http://www.ucsusa.org/clean_energy/coalvswind/index.html,
Union of Concerned Scientists
Not in My Backyard (NIMBY)?

A typical (500 megawatt) coal plant burns 1.4 million tons of coal each year. There are about 600 U.S. coal plants.
Example of Engineering Solution

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Energy Required to Make Ethanol

Make process of separating water form ethanol more effiecient
Avoid use of benzene, cyclohexane
Use a renewable resource
Vapor Adsorption Rates of Ethanol and Water on Starch (Corn Grits)

\[
W(t)/W_{\text{sat}} = \frac{\text{g}}{\text{g}}
\]

Time, hrs

85 C 100 C 90 C 80 C

Water Ethanol

This separation is kinetically controlled

(Jay Lee, AIChE J, 1991; Paul Westgate, Trans ASAE, 1993)
Mechanism: Hydrogen Bonding
SEM of surface: Horny Endosperm

Starch granules
Size of 2 to 5 μ

Protein between starch granules gives smooth surface

Kyle Beery, Ads J, 1998
SEM of surface: Floury Endosperm

Starch granules
Size of 2 to 5 µ

50% less protein gives exposed starch granules
Adsorbent: Ground Corn
Dry Regenerating Gas

Dry Alcohol

Columns Packed with Corn

Wet Alcohol

Distillation Column

Wet Regenerating Gas

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Temperature and Water Profiles at Outlet of Column

\( Y_0 = \text{Mole Fraction Water in Ethanol} \)

\( \frac{C_{ps}}{C_{pb}} > \frac{q}{Y_0} \)

at Inlet = 0.372

(Marcio Voloch, IEC, 1984)
Combined distillation and adsorption system
Industrial Scale Corn Grit Adsorption Tower
Impact

Used to process 800 million gallons ethanol / yr

Corn is both substrate and separations media. Renewable, regenerable, and recyclable. Reduced energy consumption. Regenerated using CO$_2$ co-product. Captures water and the heat that assists adsorbent regeneration.
Challenges

Utilize biomass materials from a wide range of sources:
  Cellulosics
  Fiber
  Corn

Apply biotechnology and nanotechnology to develop bio-catalytic conversion routes
  Yeasts
  Fixed bed catalysts
  Enzymes
Opportunities

Apply biotechnology to bioprocessing
Small environmental footprint
Benefits agriculture
Creates jobs
Utilize biological materials as sources of renewable energy and biodegradable chemical building blocks
Contribute to energy security
Reduce increase of global warming gases
Discovery Activities

1. **advanced pretreatments**
   to enhance the digestibility/reactivity of the fiber component (cellulose and hemicellulose) of DG,

2. **enzymatic hydrolysis of pretreated celluloses**
   to produce fermentable sugars, remove part or all of the cellulose and hemicellulose, increase feed value of residual solids,

3. **ferment hexose and pentoses using genetically engineered yeasts**
   to ethanol and their transformation to other biobased products,

4. **Bio-catalysts to make diesel from soybeans, sugars from biomass**
   convert alcohol and soybean oil to diesel

5. **Separations technology**
   energy efficient recovery form water of different bio-products

6. **comprehensive economic analysis**
   of the processes, technologies, and markets, incorporating uncertainty in key technological and market parameters.
Challenge to us all…

Personalized, distributed energy
Liquid and transportation fuels
Photovoltaics
Biofuel cells
Distributed control systems
Bio/nanotechnology (electrodes, strength/weight, insulation)
Coal, CO₂, Environment, Energy Balance
Part of the solution space is to think **Renewables**

http://engineering.purdue.edu/LORRE